Research Paper | Engineering | E-ISSN No : 2454-9916 | Volume : 9 | Issue : 7 | July 2023

SIMULTANEOUS REMOVAL OF COD AND NITRATE FROM MUNICIPAL WASTEWATER: ENHANCING TREATMENT EFFICIENCY WITH A SPOUTED BED REACTOR UTILIZING GRANULAR ACTIVATED CARBON AS BIOFILM SUPPORT MEDIUM.

Mr. Kirankumar Rathod[1], Dr. Keshava Joshi[1], Ms. Shilpa Lamani[2]

[1] Department of Chemical Engineering, SDM College of Engineering and Technology, Dharwad.

[2] Department of Mathematics, K L Deemed to be University, Guntur District, A.P.

ABSTRACT

This study investigated the performance of a spouted bed reactor for simultaneous removal of chemical oxygen demand (COD) and nitrate from wastewater using granular activated carbon (GAC) as a biofilm support medium. The reactor had a cylindrical column with a central draft tube made of polyvinyl chloride and was run continuously for 8 hours a day. The experimental wastewater had an initial concentration of 600 mg/L total COD and 40 mg/L nitrate, similar to the higher average composition of municipal wastewater. Compressed air was used to spout the solids in the draft tube, and the experiments were carried out at four different dilution rates (1.2/h, and 1.8/h) with 10 g, 20 g and 30 g loading of GAC. Effluent samples were collected at appropriate time intervals for further analysis. COD removal occurred in the riser through oxidation using air as the oxygen source, while in the annular section, carbon was used as an electron donor for the denitrification process. The results showed that the spouted bed reactor achieved COD and nitrate removal efficiencies of up to 92.5% and 96.7%, respectively, at a dilution rate of 1.2 L/h. with 30 loading. The study demonstrates the potential of spouted bed reactors with GAC as a biofilm support medium for simultaneous removal of COD and nitrate from wastewater

KEYWORDS: Spouted Bed Reactor, Granular Activated Carbon, Chemical Oxygen Demand, Nitrate, Denitrification, Biofilm Support Medium.

1. INTRODUCTION

Municipal wastewater treatment is a critical aspect of environmental protection, as it helps to prevent the pollution of water bodies and protect public health. Nitrate and COD are two of the most common pollutants found in municipal wastewater, and their removal is essntial to meet regulatory standards. Spouted bed reactors have been used in various applications, including wastewater treatment, due to their advantages such as high gas-liquid-solid contact, good mixing, and high mass transfer rates. The use of granular activated carbon (GAC) as a biofilm support medium in spouted bed reactors has been shown to enhance the removal of pollutants from wastewater. In this study, we evaluated the performance of a spouted bed reactor with GAC as a biofilm support medium for simultaneous removal of COD and nitrate from wastewater.

It is estimated that approximately 1.8 billion people will be without accessibility to clean drinking water by 2025[2]. Wastewater treatment for reuse is widely recognized as the most successful way to reduce water pollutants and improve wastewater treatment plant effluent quality (WWTPs) [3]. Wastewater reuse is a global challenge, particularly in arid regions. Chemical oxygen demand (COD) is crucial for analyzing wastewater reuse, specifically in tertiary treatment. This study aims to develop an approach for evaluating COD removal from low-strength wastewater, emphasizing the need for wastewater treatment technology to address pathogen and microorganism pollution in order to enable reuse [4]. Review of heterotrophic and autotrophic denitrifications with different food and energy sources concluded that autotrophic denitrifiers are more effective in denitrification. Autotrophs utilize carbon dioxide and hydrogen as the source of carbon substrate and electron donors, respectively [5]. Technologies use bacteria to convert ammonia and nitrate to gaseous nitrogen, N2. In this form nitrogen is inert and is released to the air[7]. Sewage treatment relies on microorganisms for biochemical transformations, with different environments influencing microbial populations and treatment outcomes. Systems aim to create targeted biochemical conditions for effective sewage treatment.

Sewage treatment involves three main biochemical transformations: removal of soluble organic matter, digestion and stabilization of insoluble organic matter, and transformation of soluble inorganic matter[8]. Sewage treatment occurs in aerobic and anaerobic environments. For potable water production, abiotic treatment steps are needed. Rivers act as natural treatment links, diluting and stabilizing treated wastewater before it's extracted and treated for municipal use.

2. MATERIALS AND METHODOLOGY.

2.1. Materials.

Sludge from a Sewage Treatment Plant (STP) in Dharwad, Karnataka, India was used for the study. The sludge was mixed with nutrient media and incubated for 144 hours, with water and fresh media added periodically. Pseudomonas spp. were observed, indicating successful adaptation. GAC particles (2.4 mm) were then added to the sludge and stirred for 48 hours to develop a biofilm. The biofilm-coated GAC particles were transferred to the reactor.

2.2. Experimental Setup

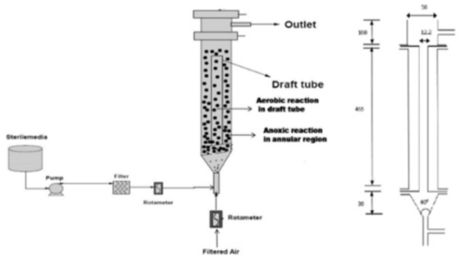

Fig.2.2.1. Spouted bed reactor

The spouted bed reactor consisted of a 2-inch cylindrical column with a 1-inch central draft tube made of polyvinyl chloride. The experimental wastewater had an initial concentration of 600 mg/L total COD and 40 mg/L nitrate. Compressed air was introduced through a filter at a controlled rate to spout the solids in the draft tube. The experiments were carried out at four different dilution rates (1.2 l/h and 1.8 l/h) with 10g, 20g and 30g loading of GAC. Effluent samples were collected at appropriate time intervals for further analysis.

2.3. Sem Analysis

SEM is a technique that uses an electron beam to analyze solid specimens. It generates signals on the sample's surface, revealing spatial variations in properties like chemical characterization and material orientation. To be analyzed, SEM samples need special preparation for electrical conductivity and stability in high vacuum and electron beam conditions. SEM is commonly used for defect analysis of semiconductor wafers. Biofilm characterization using SEM includes parameters like cell count, thickness, detachment rate, flow rate, and nutrient availability, which impact microbial process effectiveness.

3. RESULTS AND DISCUSSION.

3.1. Biofilm Characteristics

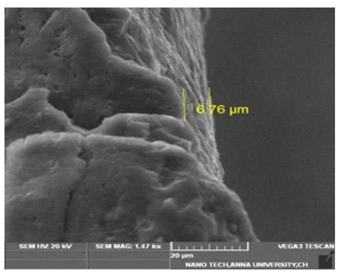

Fig.4.1 morphological characteristics of bio film

The biofilm had an average cell count of 209 per cm with a thickness of 6 µm. The detachment rate coefficient ranged from 0.0114 to 0.0366 m-1h-1, with the average biomass growth rate ranging from 0.0012 to 0.0045 kg B/m3h. The density of the biofilm was found to be 1005 kg/m3, and the dilution rate was 0.8. The pressure applied was 22 psi.

The results obtained from this study demonstrate that the biofilm had a relatively low detachment rate coefficient, indicating that it had a strong attachment to the surface. The average biomass growth rate was also relatively low, suggesting that nutrient availability may have been limited. Additionally, the biofilm was subjected to grinding or attrition, which could have affected the overall integrity of the biofilm. These findings highlight the importance of optimizing the nutrient availability and flow rate to promote the growth and stability of biofilms in microbial processes.

3.2. Effect Of Different Parameters At 10g Gac Loading
3.2.1. effect Of Different Parameters At 1.2 L/h Flowrate

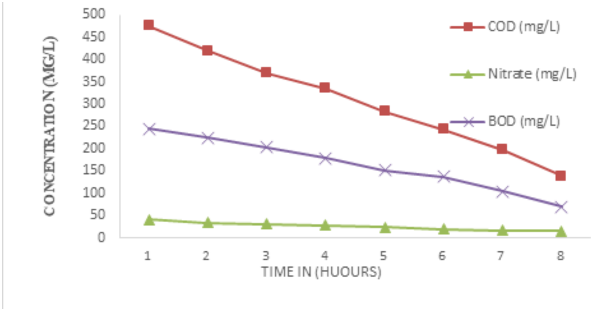

Fig.3.2.1. Effect of change in concentration of different parameters for a flowrate of 1.2l/h and GAC loading of 10g.
The decrease in the concentration of COD indicates a reduction in the amount of organic matter present in.

3.2.2. Effect Of Different Parameters At 1.8 L/h Flowrate

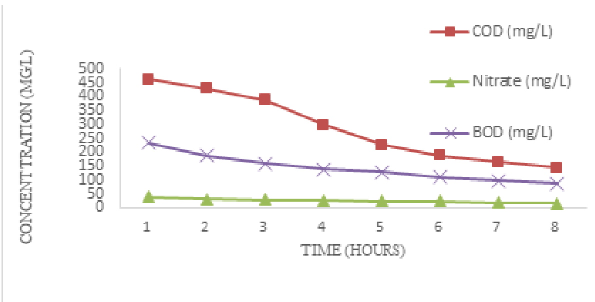

Fig.3.2.2. Effect of change in concentration of different parameters for a flowrate of 1.8l/h and GAC loading of 10g.
Decline in COD, nitrate, and BOD concentrations over the study period, suggesting an improvement in water quality.

3.3. Effect Of Different Parameters At 20g Gac Loading
3.3.1. Effect Of Different Parameters At 1.2 L/h Flowrate.

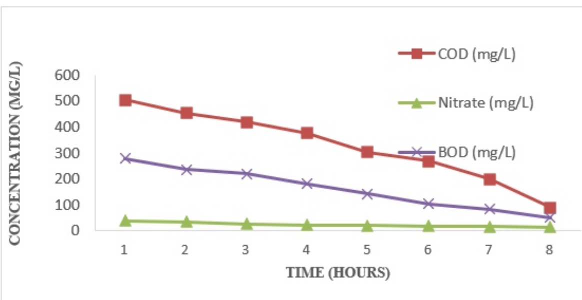

Fig.3.3.1. Effect of change in concentration of different parameters for a flowrate of 1.2l/h and GAC loading of 20g.

The water sample underwent a process of biological degradation, with microorganisms breaking down the organic matter in the sample, resulting in a decrease in COD and BOD concentrations. The decrease in Nitrate concentration could be attributed to the uptake of Nitrate by microorganisms during the biological degradation process.

3.3.2. Effect Of Different Parameters At 1.8 L/h Flowrate.

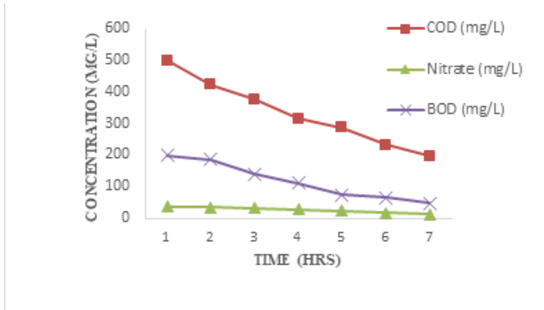

Fig.3.3.2 Effect of change in concentration of different parameters for a flowrate of 1.8l/h and GAC loading of 20g.

3.4. Effect Of Different Parameters At 30g Gac Loading
3.4.1. Effect Of Different Parameters At 1.2 L/h Flowrate

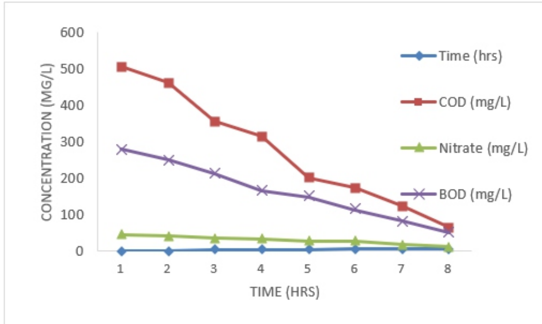

Fig.3.4.1 Effect of change in concentration of different parameters for a flowrate of 1.2l/h and GAC loading of 30g
The decreasing trends in COD, nitrate concentration, and BOD indicate potential improvements in water quality.

3.4.2. Effect Of Different Parameters At 1.8 L/h Flowrate

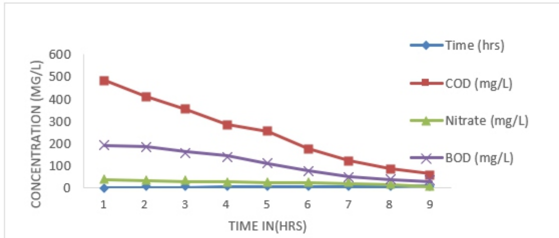

Fig.3.4.2 Effect of change in concentration of different parameters for a flowrate of 1.2l/h and GAC loading of 30g

From the figures above it can be depicted as the time lapses the COD and nitrate concentration along with BOD and TOC decreases rapidly.

The reactor studies were carried out with sewage water for three different GAC loadings (10g, 20g and 30g) and three different flow rates (1.2l/h and 1.81l/h). findings from the reactor studies using different GAC loadings and flow rates demonstrate that increasing GAC loading and dilution rate lead to a significant reduction in nitrate concentration and an increase in biomass formation. The maximum removal percentages observed were 91% for nitrate and 92% for COD, achieved with a GAC loading of 30g and a dilution rate of 1.2l/h

4. CONCLUSION

The reactor studies using different GAC loadings and flow rates demonstrated that increasing GAC loading and dilution rate have a significant positive impact on nitrate reduction and biomass formation. The results showed a maximum removal of 91% for nitrate and 92% for COD with a GAC loading of 30g and a dilution rate of 1.2l/h. The increase in GAC loading provides more surface area for bacterial attachment and growth, leading to enhanced nitrate reduction. The observed decrease in BOD concentration indicates a decline in biodegradable organic matter, which can be attributed to the metabolic action of microorganisms. These findings highlight the effectiveness of GAC as a medium for promoting nitrate removal and reducing organic pollution in sewage water.

6. REFERENCES

1. Vairavamoorthy, K., Gorantiwar, S.D., Pathirana, A., 2008. Managing urban water supplies in developing countries–Climate change and water scarcity scenarios. Physics and Chemistry of the Earth, Parts A/B/C 33 (5), 330–339.
2. Moe, C.L., Rheingans, R.D., 2006. Global challenges in water, sanitation and health. Journal of water and health 4 (S1), 41–57.
3. Zahmatkesh, S., Amesho, K.T., Sillanp¨a¨a, M., 2022a. A Critical Review on Diverse

Technologies for Advanced Wastewater Treatment During SARS-CoV-2 Pandemic: What Do We Know? Journal of Hazardous Materials Advances 7, 100121.

4. Chen, J., Wei, J., Ma, C., Yang, Z., Li, Z., Yang, X., Wang, M., Zhang, H., Hu, J., Zhang, C., 2020. Photosynthetic bacteria-based technology is a potential alternative to meet sustainable wastewater treatment requirement? Environment international 137, 105417.
5. Shahin Ghafari, Masitah Hasan, Mohamed Kheireddine Aroua,2017. Bio-electrochemical removal of nitrate from water and wastewater—A review. Bioresource Technology 99 (2008) 3965–3974.
6. A. Ruth Fernandez-Akarregi, Jon Makibar, Gartzen Lopez, Maider Amutio, Martin Olazar, Design and operation of a conical spouted bed reactor pilot plant (25kg/h) for biomass fast pyrolysis, Fuel Processing Technology, Volume 112, 2013.
7. Daniel López, Hera Vlamakis and Roberto Kolter Biofilms, Cold Spring Harb Perspect Biol. 2010 Jul; 2(7): a000398.
8. Wlodzimierz S (2012) Optimal aerations in the inverse fluidized bed biofilm reactor when used in treatment of industrial wastewaters of various strength. Adv Chem Engineer Sci 2(3):384–391.
9. Howard chioma, ibigoni howard, ette etuk Evaluation of ARIMA and artificial neural networks in prediction of effluent quality of waste water treatment system. October 2020.
10. Keshava Joshi . Lokeshwari Navalgund, et al. (2021) 'Biofilm characterization in removal of total chemical oxygen demand and nitrate from wastewater using draft tube spouted bed reactor'. Biotechnol Lett.
11. Oliveira AS, Amorim CL, Ramos MA, Mesquita DP, Inocencio P, Ferreira EC, Castro PM (2020) Variability in the composition of extracellular polymeric substances from a fullscale aerobic granular sludge reactor treating urban wastewater. J Environ Chem Eng.
12. Skoneczny, S.; Stryjewski, W.; Bizon, K.; Tabi´s, B. Three-phase fluidized bed bioreactor modelling and simulation. Biochem. Eng. J. 2017, 121, 118–130.
13. Approximate Models of Microbiological Processes in a Biofilm Formed on Fine Spherical Particles-Szymon Skoneczny and Monika Cioch-Skoneczny . Skoneczny, S.; Stryjewski, W.; Bizon, K.; Tabi´s, B. Three-phase fluidized bed bioreactor modelling and simulation. Biochem. Eng. J. 2017, 121, 118–130.
14. Approximate Models of Microbiological Processes in a Biofilm Formed on Fine Spherical Particles-Szymon Skoneczny and Monika Cioch-Skoneczny . Skoneczny, S.; Stryjewski, W.; Bizon, K.; Tabi´s, B. Three-phase fluidized bed bioreactor modelling and simulation. Biochem. Eng. J. 2017, 121, 118–130.
15. Skoneczny, S.; Cioch-Skoneczny, M. Mathematical modelling and approximate solutions for microbiological processes in biofilm through homotopy-based methods. Chem. Eng. Res. Des. 2018, 139, 309–320